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MITIGATION OF THE HEAT HAZARD IN INDUSTRIES.[1]

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The exposure of workers to excessively high temperatures and humidity is one of the most serious of the health hazards incident to occupation in many modern industrial plants, and the question of measures of effective mitigation of such conditions is important. Unusual conditions of temperature and humidity played but a minor rôle among health hazards in industrial plants until steam was substituted for water power. Since that time exposure to atmospheric conditions of high temperature and unusual humidity, coincident with the marvelous growth of industry and the invention and introduction of new machinery and various manufacturing processes, has given rise to one of the most common and serious problems of industrial hygiene. In several of the large industries of the United States, particularly in certain departments of those industries, the temperature to which workers are exposed is exceedingly high and in many instances is accompanied by unusual conditions of humidity. Moreover, such instances are to be found not only in large industrial plants where many persons are employed, but in many isolated working locations where heat as a health hazard is not generally considered, as, for example, in the kitchen of railway dining cars, where, during the rush hour, excessively high temperatures have been recorded. A partial list of the industries in which those employed are exposed to exceedingly high temperatures, and in some instances to extraordinary conditions of humidity, is as follows: Sugar refineries, paper mills, flax mills, laundries, tanneries, large kitchens, stoke holes and firerooms of ships, glass factories, steel blasts, and chemical manufactories.

Exposure to heat exists often as a compulsory hazard because the character of the manufacturing process carried on is such that a high temperature is a necessary attribute. In other instances, however, the undesirable conditions of high temperature and humidity to which many workers are exposed are due not so much to the character of the industrial process as to lack of precautions. The injurious operation of this health hazard can be either greatly mitigated or practically eliminated in nearly all occupations if due consideration be given the problem and the necessary steps taken for the protection of workers. It would seem, therefore, that methods by which this can be accomplished should be of interest and value to those interested in industrial hygiene and the acquisition of an efficient working personnel.

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[1] Read before the Section on Industrial Hygiene of the American Public Health Association, Washington, D. C., Oct. 19, 1917.

PHYSIOLOGICAL CONSIDERATIONS.

Heat Production, Heat Loss, and Heat Regulation by the Body.

Though the temperature of the body in health fluctuates somewhat during the day, it is maintained in rather narrow limits by regulation of the amount of body heat produced and the amount lost. The normal temperature of the body (about 98.5° F.) is an expression of the resulting balance between heat production and heat loss. Since the ill effects of high external temperature upon the body are the result of a disturbance of this state of equilibrium, it is necessary to consider the factors concerned in heat production, heat loss, and their regulation.

Heat Production.

The heat produced by the body is the result of the chemical processes involved in vital activity in general or the metabolism, which is supported by the food, drink, and air consumed.

Eighty per cent of the food eaten goes to furnish body heat. All energy spent in the body finally becomes heat.

Variations in heat production.—While the amount of heat produced within the body can never sink below a certain minimum, the amount will vary according to the character and extent of the metabolic processes taking place within the tissues. Muscular tissue exceeds all others in the amount of heat produced because of its mass and activity. Therefore, an increase in muscular activity, i. e., physical work, will add much to the amount of heat produced by the body. The increase in the amount of body heat produced by muscular activity is the most important from an industrial standpoint. Other sources of heat production, however, such as glandular activity and similar physiological processes, should be kept in mind. The amount of heat produced by such activity depends upon the quantity and composition of food eaten.

Heat Loss.

The loss of heat by the body is a physical process and takes place by conduction and convection, by radiation, and by evaporation. Heat is also lost to some extent in the excreta (urine and feces) and in raising food and drink to the temperature of the body, though this loss is insignificant compared with the losses mentioned above. Without means by which the body heat could be lost as it is produced, the temperature of the body would soon rise to a degree at which bioplasm is destroyed and life must cease. When the loss of body heat is only partially prevented, severe symptoms rapidly ensue.

Variation in heat loss.—The amount of heat lost by the body, by the means mentioned above, i. e., conduction, convection, radiation, and evaporation, varies according to the several external physical conditions to which the body is exposed. Under ordinary conditions of temperature and humidity, the percentage of total heat loss by each of these means is as follows: By radiation, convection, and conduction and cutaneous evaporation, about 80 per cent; by pulmonary evaporation, about 15 per cent; by heating the air inhaled, about 2.5 per cent; while about a similar amount is lost in heating the food and drink and in the excreta. Abnormal conditions of temperature and humidity alter the amount lost by each of these means. The amount lost by conduction, for instance, will depend upon the relative temperature of the surface of the body and the substance with which it is in contact. Should this substance be air, another factor is introduced, viz, that of its rate of motion. The rate of heat loss by radiation depends upon the specific radiating power of the surface of the body and upon the difference in temperature between the latter and surrounding objects, while that lost by evaporation will depend upon the amount of sweat evaporated, which in turn depends upon the temperature, relative humidity, and rate of motion of air. Radiation, conduction, and convection, considered together, are sometimes called heat transfer.

The rate of heat transfer, other conditions being equal, diminishes as the temperature of the air rises. The rate of heat loss by evaporation diminishes as the relative humidity increases. As a general effect of diminished heat loss, the temperature of the skin is raised, i. e., its specific radiating power is increased, which, besides aiding in evaporation, facilitates heat transfer. A decrease in the amount of heat lost by one means is compensated, to a certain extent, by an increase in the rate of that lost by another.

Effects of High Temperature and Humidity on the Body.

While, if the loss of body heat be prevented, severe symptoms rapidly ensue, it should be understood that the ill effects of a disturbance of the heat equilibrium do not become manifest solely in acute illness, such as heat stroke or heat exhaustion, but that the most common effect of chronic exposure to excessive heat is lowered physical efficiency of the worker so exposed and diminished resistance to fatigue and disease. While workers exposed to heat hazard eventually drop out because of decreased working powers, poor health, or some degenerative disease for which predisposition has been created by reason of the working conditions, it is unusual to find the heat hazard to which the worker has been exposed assigned its true rôle in the causation of this poor state of health. Yet the conditions of heat and humidity in many working locations are such that it is a physiological impossibility for full bodily efficiency to be maintained, not only because of the attendant discomfort, but because the body encounters physical and physiological problems with which it was never constituted to cope continuously. Many of those who have been continuously employed on the so-called "hot jobs" will state to a visitor that they have become "used to" the conditions present. In most instances, however, casual observation of the physical condition of appearance of such persons is sufficient to show that their statements are made to impress the questioner, who, as a rule, is much inconvenienced by the conditions present, and can not be held to indicate true physiological toleration. In some instances, however, limited adaptation apparently has taken place. This is very probably a result of experience rather than the true physiological adaptation, for such exposed men soon learn to reduce the amount of physical exertion to a minimum, to dress to meet the conditions, and in some instances instinctively to alter their diet.

While the body mechanism may for a time successfully cope with abnormal conditions of temperature and humidity, there seems little doubt that unless the upper range of temperature and humidity and the length of exposure are kept within certain well-defined limits, diseased conditions will result. These changes may become acutely evident at the time of or soon after the exposure, or may be gradually produced.

SYMPTOMS PRODUCED BY EXPOSURE TO HEAT.

Acute Symptoms.

Acute symptoms ensue where heat is produced more rapidly by the body than it can be dissipated, resulting in heat exhaustion or heat stroke.

Chronic Symptoms.

The effects of long continued exposure to this hazard are slow and insidious and are evidenced in degenerative changes such as arthritic and muscular rheumatism, chronic skin disorders, and arteriosclerosis. In addition, long-continued exposure to excessive heat will gradually but surely lower the general physical tone of a worker even though no special disease conditions become evident.

Effect of Radiant Heat.

Where radiant heat is concerned, the effects are generally local, i. e., the part affected is the part exposed. Changes in the skin varying from a slight reddening to a burn of the second degree may be caused without contact with the source of heat. Workers exposed to intense radiant heat often complain of their eyes, and even temporary loss of vision is a common complaint. Inflammatory conditions of the conjunctiva are common among these men and the causation of cataract has been assigned by some to exposure to radiant heat. Swollen and painful feet and rheumatoid pains of the legs and joints are frequently complained of by workers who must stand on hot surfaces.

MITIGATION OF HEAT HAZARD.

A. Removal of Source of Heat.

The temperature is frequently high in working locations because of faulty arrangement of machinery or improper housing of the department. Due to lack of forethought, sources of heat such as hot-water or steam pipes, boiler or fire rooms, steam-operated machinery, and the like, are often placed either near or in the working location of employees not concerned in their care or operation. In many instances there is no legitimate reason for this and they could be removed elsewhere without interfering with the operation or efficiency of the department, much to the comfort and efficiency of the men and the ultimate benefit of the employer. Occasionally, those occupied in the control of steam operated machinery are placed in a similar position, i. e., near the source of steam. In many cases this is unnecessary, as the control mechanism could, without impairing operation, be placed at some distance from the boilers. The working zones of those employed at boilers or furnaces are in many instances so restricted that the worker is subjected to the heat all the time he is on duty, whereas due consideration of this would have resulted in a working zone so placed or enlarged that with the exception of the time actually consumed in stoking, the worker could remain away from the heated zone without compromising efficiency in the performance of his duty. Members of the clerical force are sometimes subjected to high temperatures incident to some manufacturing process in which they are in no way concerned, because of faulty arrangement of the buildings, as, for instance, where producing departments are placed adjacent to those occupied by the clerical force. Power houses are often placed unnecessarily close to other buildings and are a source of much heat. An essential feature of plant design is that, wherever practicable, all sources of heat should be removed from working locations. In addition to this, as few workmen as possible should be exposed to heat where such exposure is unavoidable. Whenever this removal of the source of heat is not practicable, it is necessary to protect the workers by other means.

B. Protection of Workers.

The effects of undue exposure of workers may be mitigated by preventing the heat from reaching the workers after it has been radiated.' In order to minimize heat radiation, the source should be insulated. This is most satisfactorily accomplished by surrounding the source of heat with a water jacket, a hollow steel covering through which water is circulated. This method is especially useful at furnaces. Asbestos coverings have proved satisfactory in many instances, though where high temperatures must be dealt with the water jacket is better. When insulating a source of heat of large dimensions or covering extensive heat generating surfaces, such as the conduits of blast furnaces, double walls of fire brick separated by an air space are very efficient. Where insulation of the source is not practicable, other means of mitigation must be resorted to. The first step in this direction should be taken in the beginning, when the buildings to house the various departments are designed. If due consideration is given the subject at this time, much expense and labor will be saved.

Buildings devoted to hot processes should be large, high-roofed, with ample floor space, and provided with large openings in the walls and roof to facilitate natural ventilation. Such provisions will aid greatly in carrying off superheated air. In some instances it is necessary to aid natural ventilation by artificial means. Electrically driven supply and exhaust fans, if of sufficient size and properly placed and operated, are excellent. In some locations the radiant heat will be so great that the measures taken above for the protection of workers will prove inadequate. In such cases the installation of screens between the source of heat and the worker has been found to be of advantage. These screens are built of various materials according to conditions existing in the working locations, foremost among which is the character of the duties required of the worker. Brick shields are efficient, but have the disadvantage of being permanent, i. e., stationary, which in many instances is undesirable. In such cases, portable screens made of steel or steel faced with asbestos are satisfactory. In other cases where the worker must look at the source of heat in the performance of his duties, it is necessary to install transparent screens. For this purpose wire mesh may be used and the shield made either portable or stationary as the conditions demand. Wire mesh screens intercept much heat. In some cases a fine spray of water falling between the source of heat and the worker is used. Though efficient, this method should not be used except in locations where the relative humidity is low. In some instances screens, besides being necessarily transparent, must be of such a character as to permit the worker to pass beyond them toward the source of heat. The necessity of removing portable screens for this purpose and then replacing them would seriously interfere with the proper performance of the work and in some locations would be impossible. A screen which will stop a great deal of radiant heat, yet which can be readily displaced, is made of chains hung down in rows from a crossbeam. When necessary, the worker pushes them aside and passes through, but immediately upon returning to his working, is again protected.

Another method is that of causing a strong air current to pass from below upward just in front of the sources of heat. This method, while aiding ventilation to some extent, does not act as a very efficient screen. When any of the above means fail to meet the conditions, a forced air current directed from behind the worker toward the source of heat should be provided. This method has proved very satisfactory at tube-welding furnaces. The air blast must be stong. For this purpose it is necessary to install electrically driven fans of about 3 feet in diameter. None of these methods is practicable in the case of certain "hot jobs," and here it is necessary to place the protective devices on the man himself. Among these devices may be mentioned goggles, wire mesh face masks, asbestos aprons and leggins. Where employees handle hot material, metal-faced gloves give satisfaction. Wooden or green leather soled shoes, or shoes which have a layer of asbestos, cork, or similar poor conductor placed between the outer and inner layers of the sole, will greatly aid in protecting the feet of workers who are required to stand on heated surfaces, as for example, around the soaking pits in a steel plant.

The methods mentioned above are mainly of service in mitigating the effects of radiant heat. In many working locations the conditions to be met are of a different character. Here, the entire working location is superheated, often a high relative humidity exists and the measures just indicated are not adequate. In these locations we must facilitate heat loss and control the heat production of the body.

To Increase Rate of Heat Loss.

With the exception of the relatively small amount (5 per cent) of heat lost in heating food, drink, and inhaled air, and that lost in the excreta, heat loss takes place from the surface of the body. The theoretical indications, therefore, to facilitate loss by this means are to expose this surface by removing the body coverings. Under ordinary conditions, clothing lessens the amount of heat lost by the body by about 47 per cent. Experimentally, a man clothed and exposed to a temperature of 64.4° F. will lose about 79 calories [1] an hour; under the same conditions, but naked, he will lose 124 calories.[1]

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[1] Calorie (large), the amount of heat necessary to raise 1 liter of water 1 degree centrigrade.

Clothing acts as an insulator and interferes with both heat transfer and evaporation of moisture because it is usually made of substances of feeble conductivity which entangle air in the mesh. Thus, if the conductivity of silver be taken as 493, that of wool or cotton is about 0.04, and that of air is 0.000288. Therefore, where high temperature must be sustained, exposure of the body surface is indicated. This, however, can not be carried out in working locations where the abnormal conditions of temperature are due to radiant heat as here the workers are forced to wear additional clothing to avoid actual injury to the skin. In actual practice, however, it is found that by wearing clothing of a certain character, heat transfer is facilitated, for the clothes become wet with perspiration and as water is a better conductor than air, a more rapid loss of body heat takes place. It has been shown experimentally, for instance, that an arm enclosed in a calorimeter and wrapped in flannel will lose in an hour about 4.5 cal. If the flannel is wet, however, this loss is increased to 22.7 cal. In addition, evaporation takes place as rapidly from the surface of the clothing if heated from beneath the body as it will from the surface of the body itself. The type of clothing, therefore, indicated here is thin, light, and with good absorptive properties. Cotton clothing meets these requirements. However, the use of such garments adds a hazard in that the worker, after leaving his place of work in a hot and wet condition, cools off too rapidly and symptoms of internal congestion, such as muscular and arthritic pains and catarrhal conditions of the respiratory tract, may ensue. Workers can not be relied upon, either from carelessness or ignorance of the danger, to take the necessary precautions to avoid the hazard. Woolen clothing, therefore, is better, as it will perform most of the desired functions satisfactorly and yet does not allow too rapid cooling off to occur.

Relation of Humidity to Heat Loss.

The body depends upon perspiration and evaporation of sweat under normal conditions to remove about 15 per cent of the body heat. The loss by evaporation must be considerably increased if for any reason the heat loss through other paths is diminished. The most important factor governing this means of heat loss is the amount that can still be taken up by the air. This depends upon the temperature of the air. Thus at:

10° F. 1 cubic foot of air will take up 1.1 grams.
32° F. 1 cubic foot of air will take up 2.13 grams.
60° F. 1 cubic foot of air will take up 5.77 grams.
80° F. 1 cubic foot of air will take up 10.98 grams.
90° F. 1 cubic foot of air will take up 14.85 grams.
99° F. 1 cubic foot of air will take up 19.28 grams.

The water output of the body by evaporation varies inversely as the humidity of the air. The essential index, therefore, of the conditions of a working location is the wet-bulb reading, i. e., the relative humidity. Generally speaking, in no case should the air of any location where continuous work is performed be above 70° F. by the wet bulb. At 72° F., much body surface must be exposed and a perceptible air current passed over the body if work is to be performed without unduly raising the body temperature; at 82° F., a maximum amount of body surface must be exposed and a strong air current passed over the body, while if the wet bulb registers 85° F., the body temperature rises and work becomes impossible.

Air Motion.

As mentioned above, the rate of heat loss is also dependent upon the rate of air motion. In hot working zones, if the air be still, even though it be dry, the body becomes quickly surrounded by an air envelope, saturated with body moisture, which, acting like a blanket, prevents the cooling of the body by evaporation. Means, therefore, by which the air surrounding the workman on "hot jobs" can be kept in motion are indicated. Proper building design and construction with a view to adequate natural ventilation will in many instances be sufficient, but the installation of either air exhaust or supply systems, or preferably both, will cause sufficient air motion to aid materially in heat loss. The large force fans previously mentioned are very effective.

In all hot working zones the current of air should at least be perceptible, as the rate of heat loss is proportional to the square root of the velocity of the air current. Air moving at 1.5 feet per second is imperceptible, at 2.5 feet per second, barely perceptible, while air moving at the rate of 3.5 feet per second causes a perceptible draft.

Water Drinking.

Since so much body water is lost under conditions which provoke free perspiration, it is important that an ample amount of water be drunk to replenish the tissues thus deprived of their normal water content. Without this, their proper functions will be hampered and health and efficiency can not be expected. The worker should be furnished an abundant supply of water together with drinking facilities which are clean, attractive, and placed so as to be conveniently accessible at all times. The water should never be below 55° F. in temperature, as the drinking of cold water is likely to cause gastrointestinal disorders. The jet sanitary fountain is the best drinking facility. Though under ordinary conditions the amount of heat lost in bringing the temperature of water up to that of the body is small, this amount, by judicious drinking, can be increased. Water should be drunk in small quantities and at frequent intervals, not in large quantities at infrequent intervals.

Bathing.

In addition to drinking, the use of water as a bath is very beneficial in aiding heat loss by the body. These baths should be tepid, about 85° F., and the water should strike the body with force. A strong needle shower of tepid water, of short duration, followed by a brisk rub-down, will leave the skin in proper functioning condition and in addition relieve fatigue. Physiological experiments have shown that baths greatly accelerate the return to normal of the temperature of the body after it has been raised several degrees by exercise.

Reduction of the Amount of Heat Produced by the Body.

The amount of heat generated by the body may be diminished by, first, reducing the amount of physical work and, second, by regulation of the diet. With the invention of new machinery and the introduction of many labor-saving devices much physical work has been done away with, as, for example, by mechanical stoking devices. There is still, however, much work of a laborious character to be done. Such activities produce a great deal of body heat. Thus it has been shown that a soldier weighing 154 pounds while at rest produces 1.3 calories per minute, but while he marches with a load of 68 pounds, he produces 7.8 calories per minute. This amount of heat is sufficient to raise the body temperature one degree in less than nine minutes. Workers, therefore, exposed to abnormally high temperature or humidities should not be required to perform much physical work in the aggregate. This requirement has been met by having the men rest and work in alternate short spells, a method which is practical and can be successfully applied in nearly all instances where work must necessarily be performed in hot locations.

Influence of Diet.

It is worthy of note that by means of diet the rate of heat production has been experimentally increased by 44 per cent. The heat-producing values of the foodstuffs concerned in this production vary, the effectiveness of proteid, carbohydrate, and fat being as 20:10:7. Where work must be performed under heated conditions, the intake of meats and fats should be reduced and the consumption of starches, fruits, and green vegetables increased. By proper attention to the diet, therefore, the heat production of the body can be materially reduced.

The final method of heat mitigation which can still be applied, if the character of the manufacturing process is such that high temperature is a necessary attribute and the existing conditions of the working location are such that the exposure of the employees can not be prevented, is the reduction of the length of exposure. Under such conditions it is necessary to increase the force in a given location, and allow the men to work in short spells. In this way the short duration of the exposure, combined with the greater period for recuperation afforded by the long rest intervals, keeps the mechanism of the body at its highest efficiency and permits it to endure to the best of its capabilities the stress to which it is subjected during the working intervals.

THE MASSACHUSETTS ENDEMIC INDEX.

By Walter H. Brown, M. D., Epidemiologist, Massachusetts State Department of Health (now Health Officer, Bridgeport, Conn.).

The United States Public Health Service carries at the head of its department on the "Prevalence of Disease" in the Public Health Reports this statement of fact:

> No health department, State or local, can effectively prevent or control disease without a knowledge of when, where, and under what conditions cases are occurring.

One might very well add to this statement that the information should be received promptly, the cases investigated thoroughly, and a complete record made of the findings.

The fundamentals of the epidemiological control of disease are:

1. Prompt reporting of all cases of communicable diseases.
2. Prompt and thorough investigation of all outbreaks of communicable diseases.
3. An adequate follow-up system to check the value and efficiency of the methods of control.
4. Complete records.

With this information, plus sufficient statutory powers, there can be established an efficient, economic administrative control of communicable diseases.

It is not the purpose of this paper to discuss reporting, investigating and evaluating methods of communicable-disease control. The writer merely wishes to call attention to a method of using morbidity reports that has been adopted by the Massachusetts State Department of Health. This method has been developed in response to the peculiar needs of a state with a decentralized form of health organization. As used in Massachusetts, this method may not be applicable in other places, but the principle seems to be one that may be serviceable, both in State and municipal health work.